SC1161/SC1162

Energy-Efficient, Accurate Primary-Side Regulation
CV/CC Switcher for Adapters and Chargers

Product Highlights

Dramatically Simplifies CV/CC Converters

- Eliminates optocoupler and all secondary CV/CC control circuitry
- Eliminates all control loop compensation circuitry

Advanced Performance Features

- Compensates for transformer inductance tolerances
- Compensates for input line voltage variations
- Compensates for cable voltage drop
- Compensates for external component temperature variations
- Very tight IC parameter tolerances using proprietary trimming technology
- Frequency jittering greatly reduces EMI filter cost
- Even tolerances achievable with external resistor selection/trimming
- Programmable switching frequency up to 85 kHz to reduce transformer size
- Minimum operation frequency 1.4 kHz improve transient load response

Advanced Protection/Safety Features

- Auto-restart protection reduces power delivered by >90% for output short-circuit and control loop faults (open and shorted components)
- Hysteretic thermal shutdown – automatic recovery reduces power supply returns from the field
- Meets high-voltage creepage requirements between DRAIN and all other pins both on the PCB and at the package

EcoSmart™– Energy Efficient

- Easily meets all global energy efficiency regulations with no added components
- No-load consumption at 230 VAC input with bias winding <75 mW
- ON/OFF control provides constant efficiency down to very light loads – ideal for CEC regulations
- No current sense resistors – maximizes efficiency

Green Package

- Halogen free and RoHS compliant package

Applications

- Chargers for cell/cordless phones, PDAs, MP3/portable audio devices, adapters, etc.

Description

The SC1161/SC1162 dramatically simplifies low power CV/CC charger designs by eliminating an optocoupler and secondary control circuitry. The device introduces a revolutionary control technique to provide very tight output voltage and current regulation, compensating for transformer and internal parameter tolerances along with input voltage variations.

The device incorporates a 725 V power MOSFET, a novel ON/OFF control state machine, a high-voltage switched current source for self biasing, frequency jittering, cycle-by-cycle current limit and hysteretic thermal shutdown circuitry onto a monolithic IC.

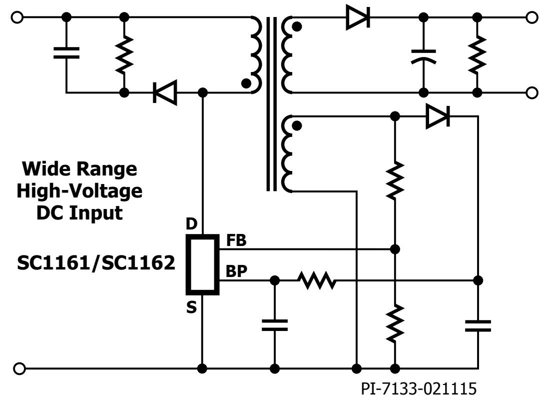

Figure 1. Typical Application – Not a Simplified Circuit.

Output Power Table

Product³	90-264 VAC	
	D (SO-8) Package	
	Adapter¹	**Open Frame²**
SC1161D	6.5 W	7.5 W
Product³	**K (eSOP) Package**	
	Adapter¹	**Open Frame²**
SC1161K	10 W	11 W
SC1162K	12 W	12 W

Table 1. Output Power Table.

Notes:
1. Minimum continuous power in a typical non-ventilated enclosed adapter measured at +50 °C ambient, device $T_J \le 100$ °C.
2. Maximum practical continuous power in an open frame design with adequate heat sinking, measured at +50 °C.
3. Package: D: SO-8C, K: eSOP-12B.

SC1161/SC1162 Output Cable Voltage Drop Compensation

Device	Output Voltage Change Factor (±1%)
SC1161/SC1162D/K0	1.02
SC1161/SC1162D/K1	1.04
SC1161/SC1162D/K2	1.06
SC1161/SC1162D/KZ	1.01

Table 2. Cable Compensation Change Factor vs. Device.

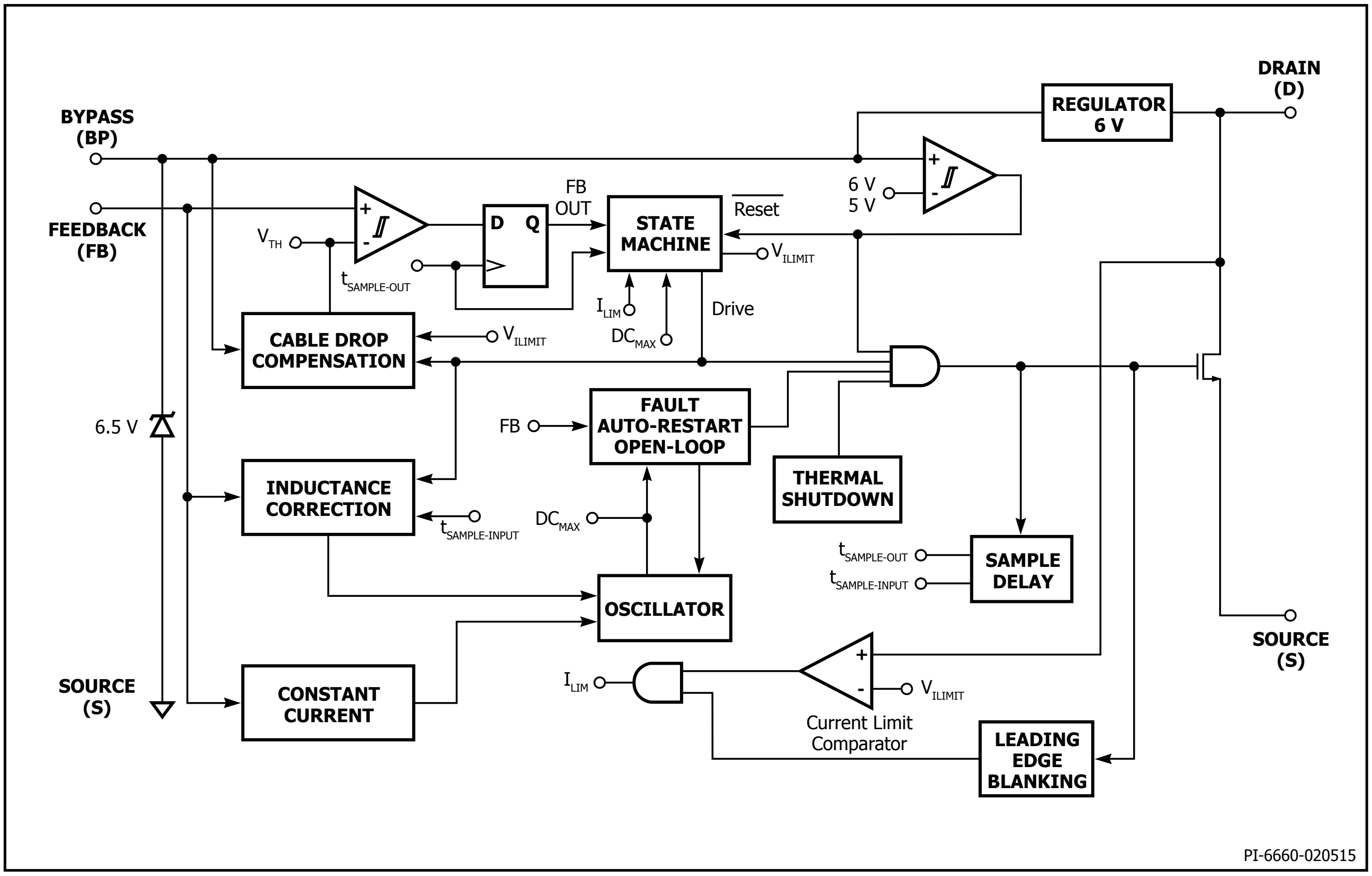

Figure 2 Functional Block Diagram.

Pin Functional Description

DRAIN (D) Pin:
This pin is the power MOSFET drain connection. It provides internal operating current for both start-up and steady-state operation.

BYPASS (BP) Pin:
This pin is the connection point for an external 1 µF bypass capacitor for the internally generated 6 V supply.

FEEDBACK (FB) Pin:
During normal operation, switching of the power MOSFET is controlled by this pin. This pin senses the AC voltage on the bias winding. This control input regulates both the output voltage in CV mode and output current in CC mode based on the flyback voltage of the bias winding. The internal inductance correction circuit uses the forward voltage on the bias winding to sense the bulk capacitor voltage.

SOURCE (S) Pin:
This pin is internally connected to the output MOSFET source for high-voltage power and control circuit common returns.

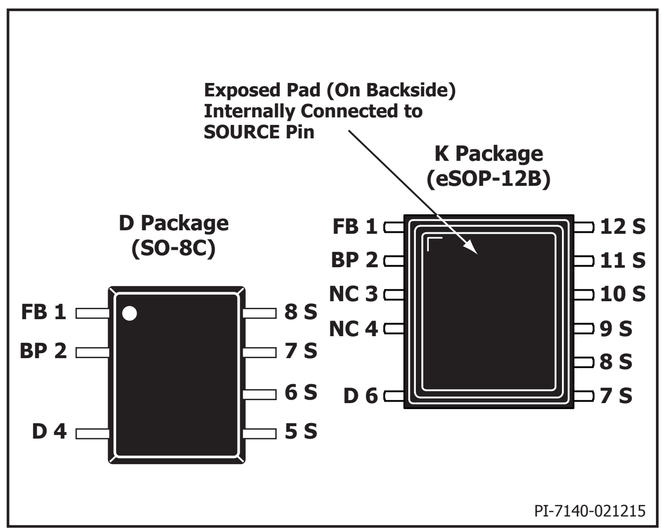

Figure 3. Pin Configuration.

SC1161/SC1162 Functional Description

The SC1161/SC1162 combines a high-voltage power MOSFET switch with a power supply controller in one device. Similar to the LinkSwitch-LP and TinySwitch-III it uses an ON/OFF control to regulate the output voltage. In addition, the switching frequency is modulated to regulate the output current to provide a constant current characteristic. The SC1161/SC1162 controller consists of an oscillator, feedback (sense and logic) circuit, 6 V regulator, over-temperature protection, frequency jittering, current limit circuit, leading-edge blanking, inductance correction circuitry, frequency control for constant current regulation and on/off state machine for CV control.

Inductance Correction Circuitry

If the primary magnetizing inductance is either too high or low the converter will automatically compensate for this by adjusting the oscillator frequency. Since this controller is designed to operate in discontinuous-conduction mode the output power is directly proportional to the set primary inductance and its tolerance can be completely compensated with adjustments to the switching frequency.

Constant Current (CC) Operation

As the output voltage and therefore the flyback voltage across the bias winding ramps up, the FEEDBACK pin voltage increases. The switching frequency is adjusted as the FEEDBACK pin voltage increases to provide a constant output current regulation. The constant current circuit and the inductance correction circuit are designed to operate concurrently in the CC region.

Constant Voltage (CV) Operation

As the FEEDBACK pin approaches 2 V from the constant current regulation mode, the power supply transitions into CV operation. The switching frequency at this point is at its maximum value, corresponding to the peak power point of the CV/CC characteristic. The controller regulates the FEEDBACK pin voltage to remain at FEEDBACK pin threshold (V_{FBTH}) using an on/off state-machine. The FEEDBACK pin voltage is sampled 2.5 μs after the turn-off of the high-voltage switch. At light loads the current limit is also reduced to decrease the transformer flux density and the FEEDBACK pin sampling is done earlier.

Output Cable Compensation

This compensation provides a constant output voltage at the end of the cable over the entire load range in CV mode. As the converter load increases from no-load to the peak power point (transition point between CV and CC) the voltage drop introduced across the output cable is compensated by increasing the FEEDBACK pin reference voltage. The controller determines the output load and therefore the correct degree of compensation based on the output of the state machine. The amount of cable drop compensation is determined by the third digit in the device part number.

Auto-Restart and Open-Loop Protection

In the event of a fault condition such as an output short or an open loop condition the SC1161/SC1162 enters into an appropriate protection mode as described below.

In the event the FEEDBACK pin voltage during the flyback period falls below 0.7 V before the FEEDBACK pin sampling delay (~2.5 μs) for a duration in excess of ~300 ms auto-restart on-time ($t_{AR\text{-}ON}$) the converter enters into auto-restart, wherein the power MOSFET is disabled for 1500 ms. The auto-restart alternately enables and disables the switching of the power MOSFET until the fault condition is removed.

In addition to the conditions for auto-restart described above, if the sensed FEEDBACK pin current during the forward period of the conduction cycle (switch "on" time) falls below 120 μA, the converter annunciates this as an open-loop condition (top resistor in potential divider is open or missing) and reduces the auto-restart time from 300 ms to approximately 6 clock cycles (90 μs), whilst keeping the disable period of 2 seconds.

Over-Temperature Protection

The thermal shutdown circuitry senses the die temperature. The threshold is set at 142 °C typical with a 60 °C hysteresis. When the die temperature rises above this threshold (142 °C) the power MOSFET is disabled and remains disabled until the die temperature falls by 60 °C, at which point the MOSFET is re-enabled.

Current Limit

The current limit circuit senses the current in the power MOSFET. When this current exceeds the internal threshold (I_{LIMIT}), the power MOSFET is turned off for the remainder of that cycle. The leading edge blanking circuit inhibits the current limit comparator for a short time (t_{LEB}) after the power MOSFET is turned on. This leading edge blanking time has been set so that current spikes caused by capacitance and rectifier reverse recovery time will not cause premature termination of the MOSFET conduction. The SC1161/SC1162 also contains a "di/dt" correction feature to minimize CC variation across the input line range.

6 V Regulator

The 6 V regulator charges the bypass capacitor connected to the BYPASS pin to 6 V by drawing a current from the voltage on the DRAIN, whenever the MOSFET is off. The BYPASS pin is the internal supply voltage node. When the MOSFET is on, the device runs off of the energy stored in the bypass capacitor. Extremely low power consumption of the internal circuitry allows the SC1161/SC1162 to operate continuously from the current drawn from the DRAIN pin however for the best no-load input power, the BYPASS pin should be supplied current of I_{S1} from the bias winding at no-load conditions. A bypass capacitor value of 1 μF is sufficient for both high frequency decoupling and energy storage.

Absolute Maximum Ratings[1,5]

DRAIN Voltage ....-0.3 V to 725 V
DRAIN Pin Peak Current: SC1161 .... 670 (1003) mA[4]
SC1162 ....718 (1076) mA[4]
Peak Negative Pulsed Drain Current...................................-100 mA[2]
FEEDBACK Pin Voltage .... -0.3 to 9 V
FEEDBACK Pin Current ....100 mA
BYPASS Pin Voltage .... -0.3 to 9 V
Storage Temperature .... -65 to 150 °C
Operating Junction Temperature[2]................................ -40 to 150 °C
Lead Temperature .... 260 °C[3]

Notes:
1. All voltages referenced to SOURCE, T_A = 25 °C.
2. Duration not to exceed 2 ms.
3. 1/16 in. from case for 5 seconds.
4. The higher peak DRAIN current is allowed while the DRAIN voltage is simultaneously less than 400 V.
5. Maximum ratings specified may be applied, one at a time without causing permanent damage to the product. Exposure to Absolute Maximum ratings for extended periods of time may affect product reliability.

Thermal Resistance

Thermal Resistance: D Package:
(θ_{JA}) ....100 °C/W[2], 80 °C/W[3]
(θ_{JC})[1] ....30 °C/W
K Package
(θ_{JA}) .... 45 °C/W[5], 38 °C/W[6]
(θ_{JC}) ....2 °C/W[4]

Notes:
1. Measured on pin 8 (SOURCE) close to plastic interface.
2. Soldered to 0.36 sq. in. (232 mm^2), 2 oz. (610 g/m^2) copper clad.
3. Soldered to 1 sq. in. (645 mm^2), 2 oz. (610 g/m^2) copper clad.
4. Measured at the back surface of tab.
5. Soldered (including exposed pad for K package) to typical application PCB with a heat sinking area of 0.36 sq. in. (232 mm^2), 2 oz. (610 g/m^2) copper clad.
6. Soldered (including exposed pad for K package) to typical application PCB with a heat sinking area of 1 sq. in. (645 mm^2), 2 oz. (610 g/m^2) copper clad.

Parameter	Symbol	Conditions SOURCE = 0 V; T_J = 0 to 100 °C (Unless Otherwise Specified)		Min	Typ	Max	Units
Control Functions							
Programmable Maximum Frequency	f_{OSC}	T_J = 25 °C $t_{ON} \times I_{FB}$ = 1.4 mA-µs See Note A, F	$V_{FB} = V_{FBth}$			85	kHz
Minimum Operation Frequency	$f_{OSC(MIN)}$	T_J = 25 °C $V_{FB} = V_{FBth}$	SC1161		760		Hz
			SC1162		560		
Frequency Ratio (Constant Current)	$f_{RATIO(CC)}$	T_J = 25 °C Between V_{FB} = 1.3 V and V_{FB} = 1.9 V		1.42	1.50	1.53	
Frequency Ratio (Inductance Correction)	$f_{RATIO(IC)}$	Between $t_{ON} \times I_{FB}$ = 1.4 mA and $t_{ON} \times I_{FB}$ = 2 mA-µs		1.16	1.21	1.26	
Frequency Jitter		Peak-to-Peak Jitter Compared to Average Frequency, T_J = 25 °C			±7		%
Maximum Duty Cycle	DC_{MAX}	See Note D, E			55		%
FEEDBACK Pin Voltage	V_{FBth}	T_J = 25 °C C_{BP} = 1 µF	SC1161/SC1162D/K0	1.915	1.940	1.965	V
			SC1161/SC1162D/K1	1.955	1.980	2.005	
			SC1161/SC1162D/K2	1.995	2.020	2.045	
			SC1161/SC1162D/KZ	1.915	1.940	1.965	

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Parameter	Symbol	Conditions SOURCE = 0 V; T_J = 0 to 100 °C (Unless Otherwise Specified)		Min	Typ	Max	Units
Control Functions (cont.)							
FEEDBACK Pin Voltage at Turn-Off Threshold	$V_{FB(AR)}$			1.13	1.22	1.31	V
Minimum Switch ON-Time	$t_{ON(MIN)}$	See Note E			700		ns
FEEDBACK Pin Sampling Delay	t_{FB}			2.55	2.75	2.95	µs
DRAIN Supply Current	I_{S1}	FB Voltage > V_{FBth} (MOSFET Not Switching)			300	380	µA
	I_{S2}	Feedback Voltage = V_{FBth} -0.1 V, Switch ON-Time = t_{ON} (MOSFET Switching at f_{OSC})	SC1161		600	680	µA
			SC1162		700	780	
BYPASS Pin Charge Current	I_{CH1}	V_{BP} = 0 V	SC1161	-7.5	-6.1	-3.5	mA
			SC1162	-7.5	-6.1	-3.5	
	I_{CH2}	V_{BP} = 4 V	SC1161	-7	-4.2	-2.0	
			SC1162	-7	-4.2	-2.0	
BYPASS Pin Voltage	V_{BP}			5.65	5.90	6.25	V
BYPASS Pin Voltage Hysteresis	V_{BPH}			0.70	0.95	1.20	V
BYPASS Pin Shunt Voltage	V_{SHUNT}			6.2	6.4	6.8	V
Circuit Protection							
Current Limit	I_{LIMIT}	di/dt = 120 mA/µs T_J = 25 °C	SC1161	446	480	513	
		di/dt = 130 mA/µs T_J = 25 °C	SC1162	484	520	556	
Minimum Current Limit Scale Factor	$I_{LIMIT(MIN)}$			0.28	0.32	0.37	
Normalized Output Current	I_O	T_J = 25 °C		0.975	1.000	1.025	
Leading Edge Blanking Time	t_{LED}	T_J = 25 °C Set Note E		125	170		ns
Thermal Shutdown Temperature	t_{SD}			135	142	150	°C
Thermal Shutdown Hysteresis	t_{SDH}				60		°C

Parameter	Symbol	Conditions SOURCE = 0 V; T_J = 0 to 100 °C (Unless Otherwise Specified)		Min	Typ	Max	Units
Output							
ON-State Resistance	$R_{DS(ON)}$	SC1161 I_D = 96 mA	T_J = 25 °C		4.8	5.8	Ω
			T_J = 100 °C		7.2	8.5	
		SC1162 I_D = 105 mA	T_J = 25 °C		3.1	3.8	
			T_J = 100 °C		4.6	5.5	
OFF-State Leakage	I_{DSS1}	V_{DS} = 560 V T_J = 125 °C, See Note C				50	µA
	I_{DSS2}	V_{DS} = 375 V T_J = 50 °C			15		
Breakdown Voltage	BV_{DSS}	T_J = 25 °C		725			V
DRAIN Supply Voltage				50			V
Auto-Restart ON-Time	t_{AR-ON}	See Notes A, E			300		ms
Auto-Restart OFF-Time	t_{AR-OFF}				1.5		s
Open-Loop FEEDBACK Pin Current Threshold	I_{OL}	See Note E			-120		µA
Open-Loop ON-Time		See Note E			90		µs

NOTES:

A. Auto-restart ON-time is a function of switching frequency programmed by $t_{ON} \times I_{FB}$ and minimum frequency in CC mode.

B. The current limit threshold is compensated to cancel the effect of current limit delay. As a result the output current stays constant across the input line range.

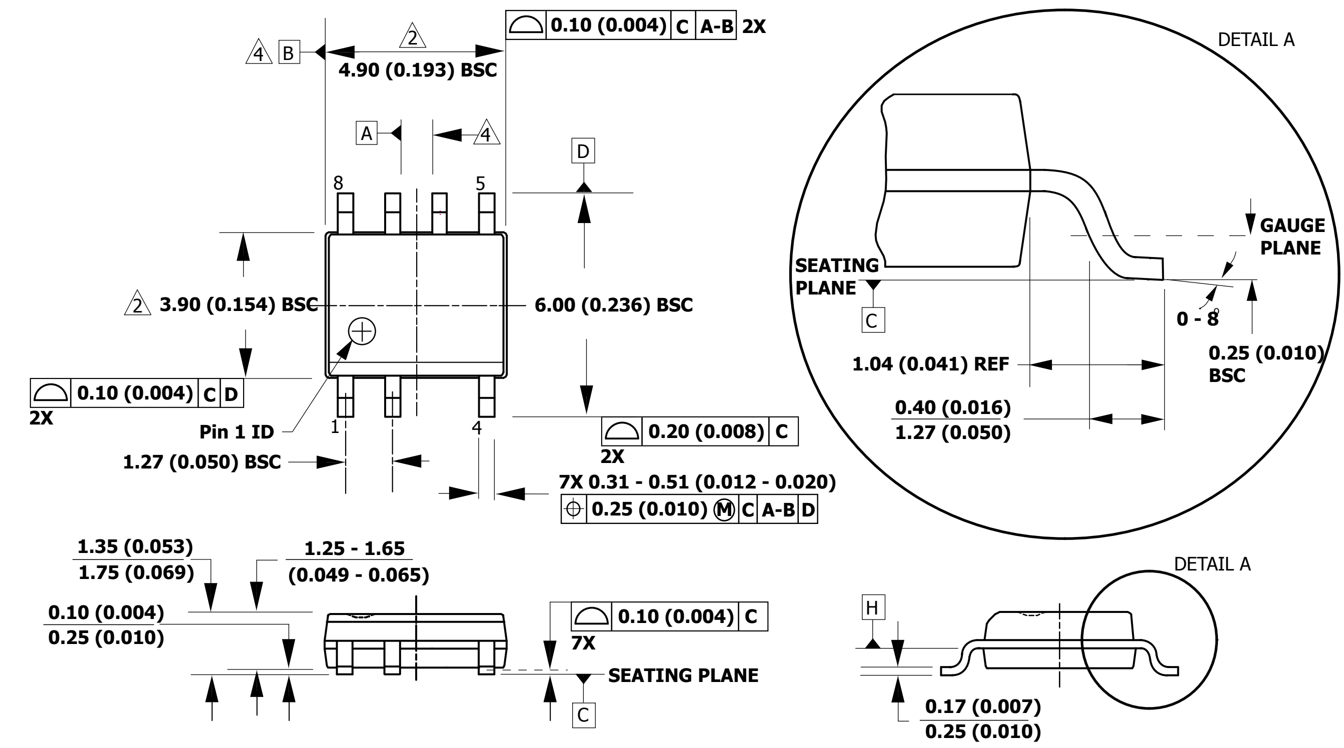
C. I_{DSS1} is the worst-case OFF-state leakage specification at 80% of BV_{DSS} and maximum operating junction temperature. I_{DSS2} is a typical specification under worst-case application conditions (rectified 265 VAC) for no-load consumption calculations.

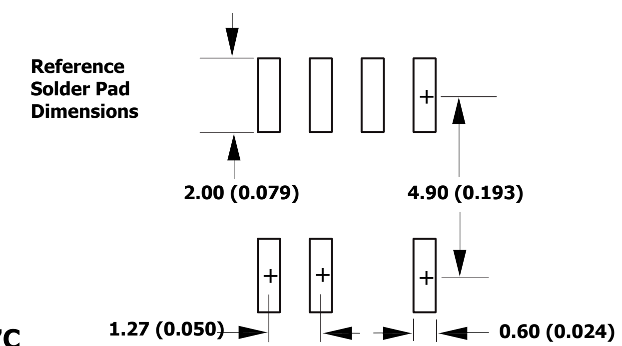
D. When the duty-cycle exceeds DC_{MAX} the SC1161/SC1162 operates in on-time extension mode.

E. This parameter is derived from characterization.

F. The switching frequency is programmable between 60 kHz to 85 kHz.

SO-8C (D Package)





Notes:

1. JEDEC reference: MS-012.
2. Package outline exclusive of mold flash and metal burr.
3. Package outline inclusive of plating thickness.
4. Datums A and B to be determined at datum plane H.
5. Controlling dimensions are in millimeters. Inch dimensions are shown in parenthesis. Angles in degrees.

D07C

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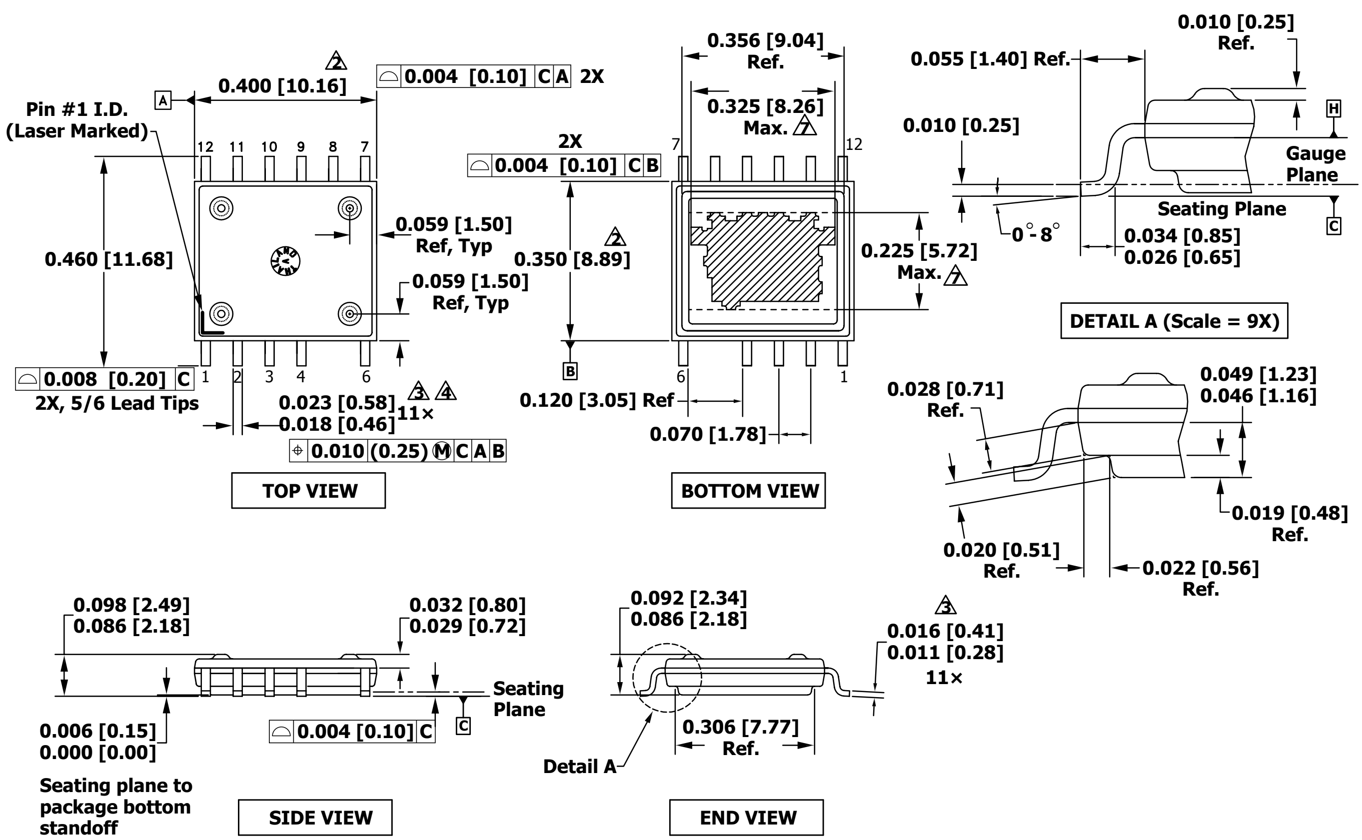
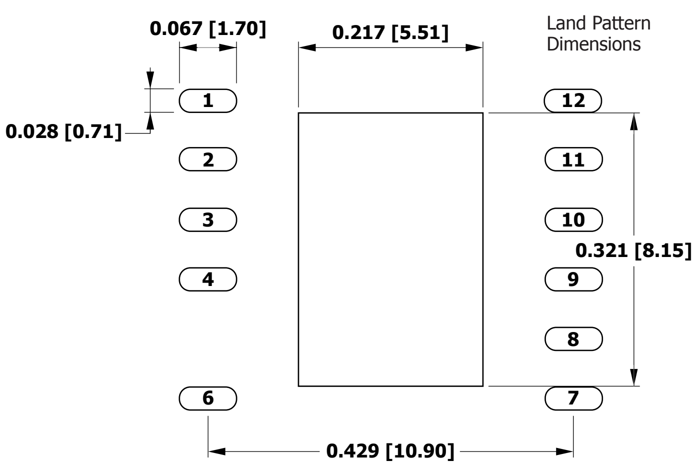
eSOP-12B (K Package)





Notes:

1. Dimensioning and tolerancing per ASME Y14.5M-1994.
2. Dimensions noted are determined at the outermost extremes of the plastic body exclusive of mold flash, tie bar burrs, gate burrs, and interlead flash, but including any mismatch between the top and bottom of the plastic body. Maximum mold protrusion is 0.007 [0.18] per side.
3. Dimensions noted are inclusive of plating thickness.
4. Does not include interlead flash or protrusions.
5. Controlling dimensions in inches [mm].
6. Datums A and B to be determined at Datum H.
7. Exposed pad is nominally located at the centerline of Datums A and B. "Max" dimensions noted include both size and positional tolerances.

PI-5748a-020515

Notes

Revision	Notes	Date
A	Initial Release.	10/13
B	Updated $f_{RATIO(CC)}$ and t_{FB} parameters. Updated to new Brand Style.	02/15
C	MOSFET disabled time corrected in Auto-Restart and Open-Loop Protection section. Removed $f_{OSC(AR)}$ and updated t_{AR-ON} parameter.	04/15

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